b. Effects of interference on analog host FM performance

First-adjacent channel interference

Interference from first-adjacent hybrid IBOC channels located ±200 kHz from the host signal can be derived from the relationship of the adjacent signals shown in the plot of Figure 10.

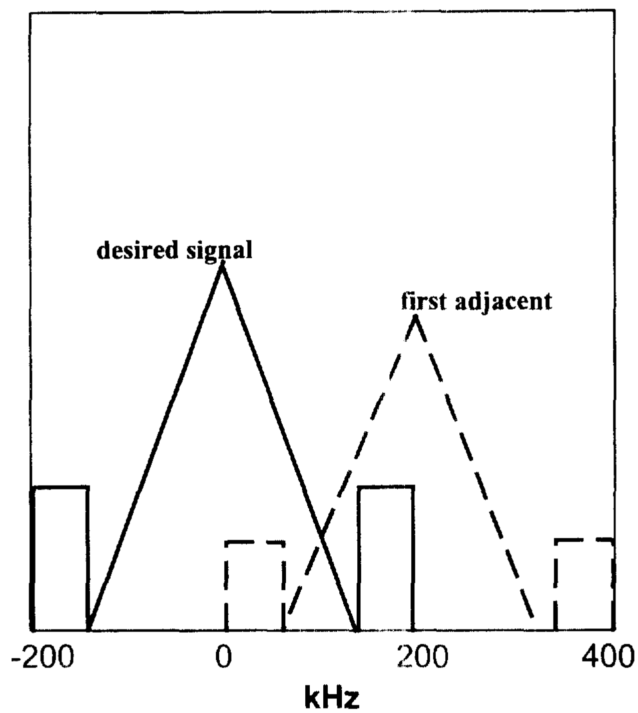

Figure 10 - Interference Scenario Showing Hybrid First Adjacent at -6 dB

Simulations have set the static power of the analog portion of the hybrid interferer to be 6 dB below the desired host FM power (maximum first adjacent level at protected contour). Simulation results show that introduction of a -6 dB hybrid IBOC first adjacent channel degrades the SNR in the modeled receiver at the 54 dBu contour to about 50 dB. Degradation in typical receivers caused by first-adjacent analog interference was characterized for five different radios in an EIA study.[69] The results indicate that degradation from the analog portion of a first-adjacent hybrid signal in typical receivers (automotive, home, and boombox) should mask additional interference introduced by the digital portion [70]

Second adjacent channel interference

Interference from second adjacent hybrid IBOC channels located ±400 kHz from the host signal can be derived from the relationship of the adjacent signals shown in the plot of Figure 11.

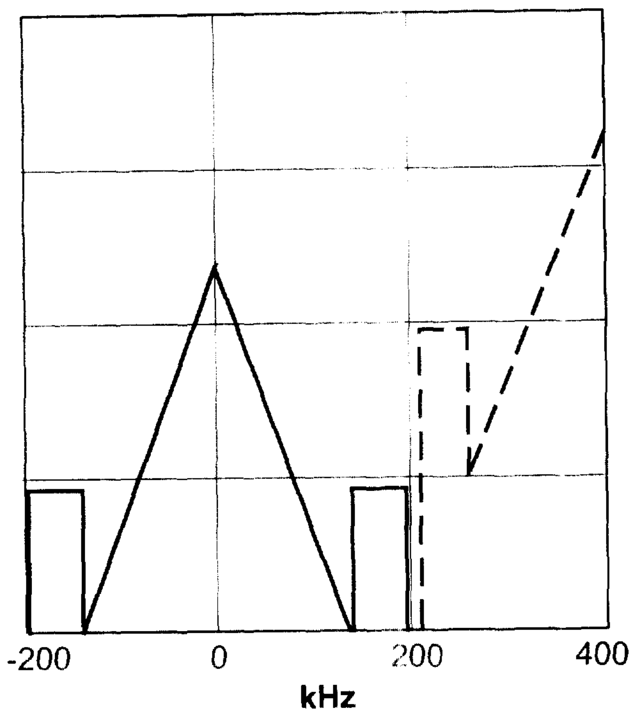

Figure 11 - Interference Scenario Showing Hybrid Second Adjacent

[69] "Digital Audio Radio Laboratory Tests Transmission Quality Failure Characterization and Analog Compatibility," Appendix H, dated Aug. 11, 1995

[70] *See* Appendix E, Section 4.2.12.

Figure 11 illustrates that the digital sidebands of the hybrid second adjacent signal fall well outside the bandwidth of the desired FM signal. Likewise, the all-digital sidebands also lie well outside the analog FM receiver passband. FM pre-detection filtering in the receiver front end should reject most of their energy. As a result, the effects of second-adjacent hybrid and all-digital IBOC signals should be negligible.

Co-channel Interference

Interference from a hybrid co-channel will be dominated by the analog portion of the hybrid signal. As a result, the performance of a desired analog signal in the presence of a hybrid IBOC co-channel should be similar to the performance currently exhibited by analog FM. The analog portion of a co-channel interferer is not present in the all-digital system. In addition, the digital energy is concentrated away from the center of the desired channel. As a result, the interference from a co-channel all-digital signal should be far less than that currently incurred from analog FM co-channel signals.

4. <u>Summary</u>

The IBOC signal has been designed to be compatible with both existing and future radio frequency environments of IBOC signals. In addition, IBOC signals will provide robust digital coverage, even in the presence of multipath fading and strong interference. Indeed, simulations indicate that in many instances, the digital coverage will extend to the protected coverage areas of the existing analog station, with significant margin

VII. USADR AM IBOC DAB SYSTEM

A. System Description

The USADR AM IBOC DAB system contains the same four basic components as the FM system: the modem, which modulates and demodulates the signal; the codec, which source encodes and decodes the audio signal; FEC coding and interleaving; and blending. All of these core functional areas have been designed and integrated to produce a system that complies with the primary functional requirements described above.

USADR evaluated several modulation techniques for the IBOC DAB AM system before selecting 32 Quadrature Amplitude Modulation ("QAM"). Because 32-QAM has a bandwidth efficiency of five bits per second per Hertz, it supports an information bit rate that is sufficient for transmission of "FM-like" audio quality in the bandwidth available. The AM system incorporates the same multi-carrier OFDM approach in which many QAM carriers are frequency-division multiplexed in an orthogonal fashion such that each carrier does not interfere with each adjoining carrier.

As discussed above, USADR will use the MPEG AAC codec in its IBOC DAB system. The AAC codec compresses the CD bit stream to a maximum audio rate of 48 kbps, delivering audio that the listener will perceive to be "FM-like." The system also operates at audio rates of 32 kbps and 16 kbps. 32 kbps rate provides more robust operation under interference conditions and delivers quality stereo. 16 kbps offers the most robust operation by delivering noise-free monaural digital audio. Use of the AAC codec meets the raw throughput requirement of the modulation and FEC coding techniques. In addition, special error concealment techniques employed by the codec help to ensure graceful degradation of the received digital signal.[72]

As with the FM component of the IBOC DAB system, forward error correction and interleaving greatly improve the reliability of the transmitted information. Carrier by carrier equalization is used to insure that the phase and amplitude of the subcarriers is sufficiently maintained to ensure proper recovery of the digital information. The equalization has been shown to deal adequately with channel perturbances from grounded conductive structures and to improve reception. The combination of these advanced FEC coding and interleaving techniques, together with use of an equalizer, allow the IBOC system to deliver "FM-like" audio in a mobile environment.[73]

The AM system uses blend and time diversity in the same manner as the FM system. Time diversity between two independent transmissions of the same audio source is used to provide robust reception during outages typical of a mobile environment. When the primary digital signal is corrupted, the receiver blends to the back-up audio, which, by virtue of its time diversity with the primary signal, does not experience the outage.[74] The blend feature also provides a means of quickly acquiring the signal upon tuning or re-acquisition.

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[71] *See* Appendix F.

[72] Additional information on the AAC codec is contained in Appendix J.

[73] The results of simulations and analyses are given in Appendix H.

[74] *See* Appendix K for a more detailed discussion of time diversity and blend.

The AM hybrid signal is shown in Figure 12 The hybrid AM IBOC DAB signal is comprised of the ±5 kHz band limited analog AM modulation and 20 kHz of digital carriers. Quadrature digital carriers are added under the analog signal at a level that is sufficient to ensure reliable digital service, yet avoid harmful interference to the host signal.

Currently, the U.S. AM band allocation plan assigns AM stations 20 kHz total bandwidth with stations spaced at 10 kHz intervals. The USADR hybrid mode IBOC DAB system reduces the total analog bandwidth to 10 kHz to prevent interference to the digital sidebands which are placed in the remaining 5 kHz on either side of the analog signal. This change in total analog bandwidth will need to be adopted when an AM station moves from analog-only to hybrid mode. The change in bandwidth, however, will have no discernible impact on listeners dependent on the analog signal because AM receivers in use today typically limit audio bandwidth to less than 5 kHz.[75]

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[75] National Association of Broadcasters, *AM Technical Improvement* (1984).

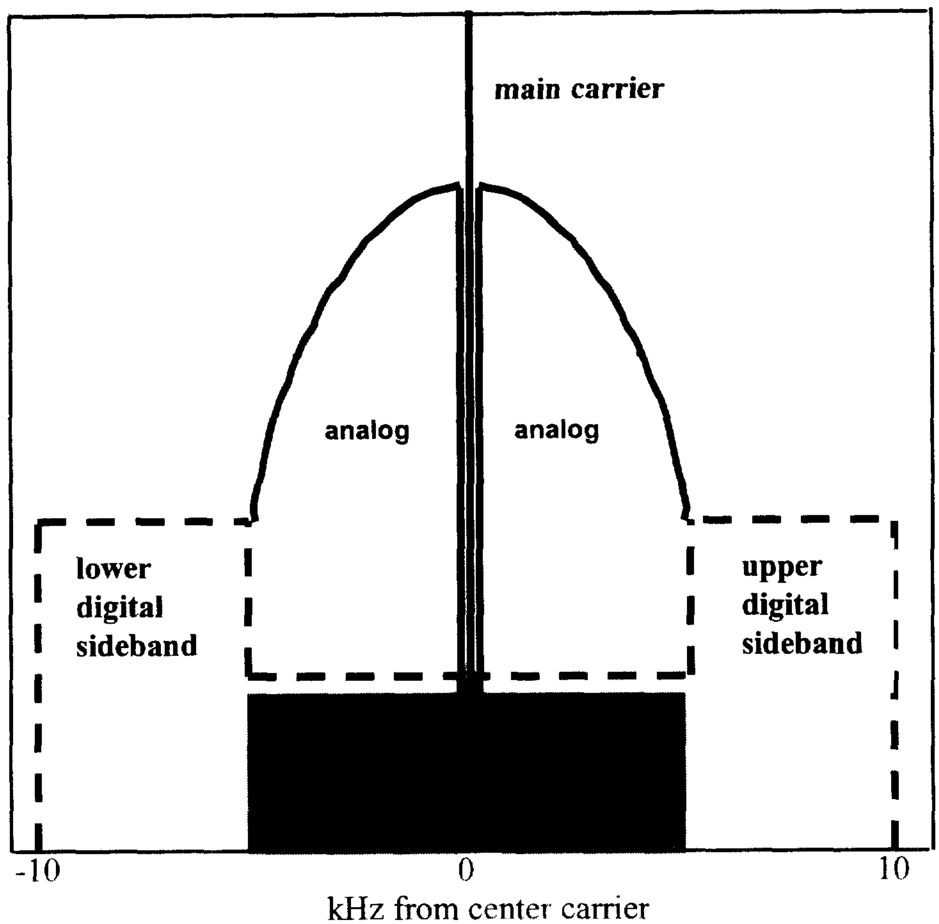

Figure 12 – Hybrid AM IBOC Power Spectral Density

As shown in Figure 14, the principal difference between the hybrid mode and the all-digital mode is deletion of the analog signal, the increase in power of the quadrature carriers that were previously under the analog signal and the addition of a low bit rate, digital back-up and tuning channel. The additional power in the all-digital waveform increases robustness and the "stepped" waveform is optimized for performance under strong adjacent channel interference.

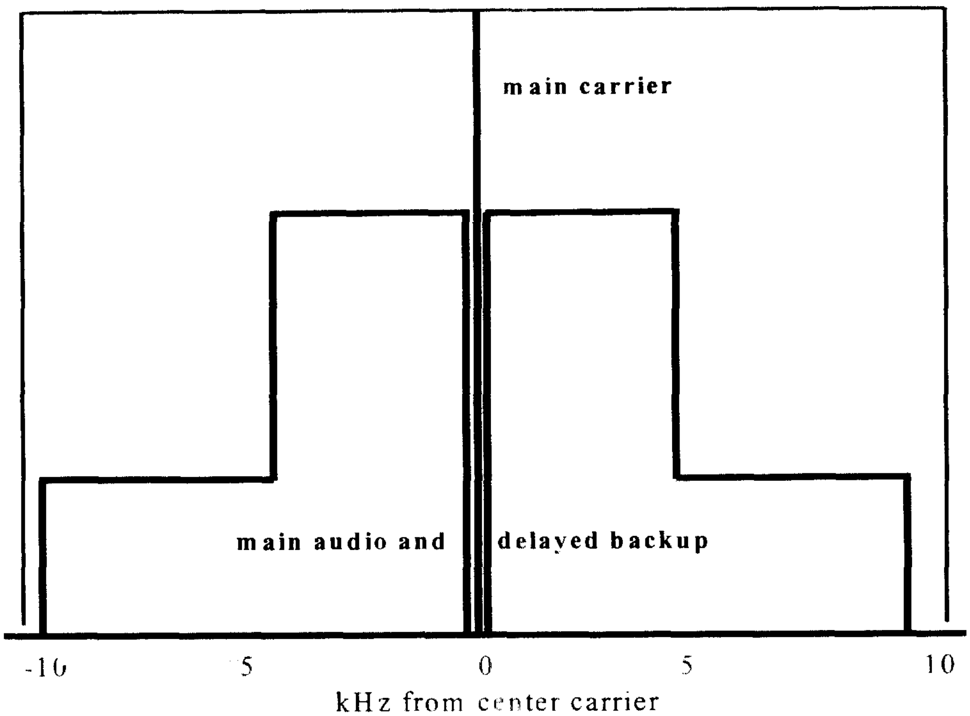

Figure 13 – All-Digital AM IBOC Signal

A functional block diagram of the hybrid AM IBOC transmitter is presented in Figure 14. The input audio source feeds a L + R monaural signal to the analog AM path and a stereo audio signal to the DAB codec.[76] The DAB path digitally compresses the audio signal in the audio encoder (codec). The bit stream out of the audio encoder is encoded with the FEC block code and interleaved. The resulting bit stream is combined into a modem frame and OFDM

[76] IBOC DAB cannot be transmitted simultaneously with AM stereo as both systems use the quadrature relationship with the analog signal. However, the loss of the stereo signal by the very few stations currently employing stereo in the AM band is more than offset by access to the higher audio quality digital signal.

modulated to produce a DAB baseband signal. Diversity delay is introduced in the analog AM path, passed through the station's existing analog audio processor, and band limited to 5 kHz. The processed analog audio is summed with the digital carriers in the IBOC exciter. This baseband signal is converted to magnitude ρ and phase ϕ for amplification in the station's existing analog transmitter.[77]

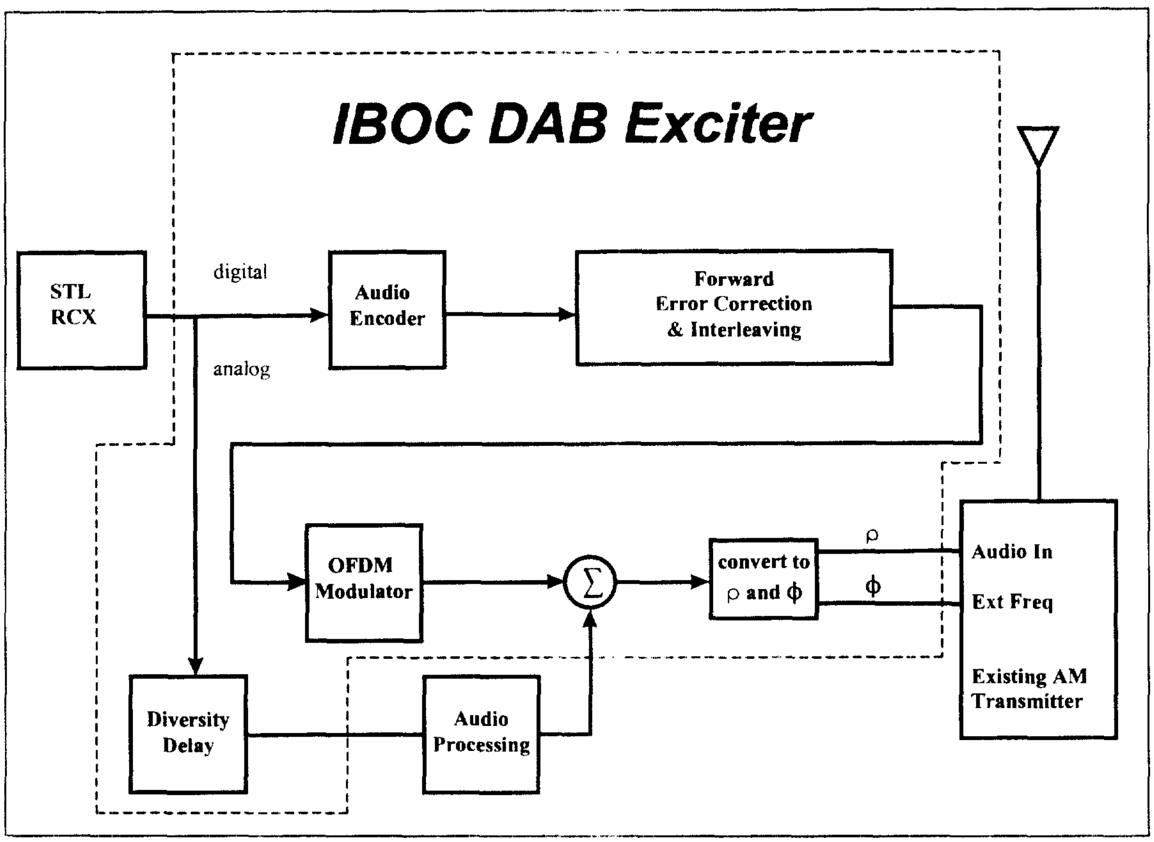

Figure 14 – Hybrid AM IBOC Transmitter Block Diagram

The audio input simultaneously feeds the main channel audio encoder and the diversity delay. The signal then follows two identical signal paths and is encoded with the FEC block

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[77] Details such as data insertion and synchronization have been omitted here for simplicity.

code and interleaved. The resulting bit streams are combined into a modem frame and OFDM modulated to produce a DAB baseband signal.

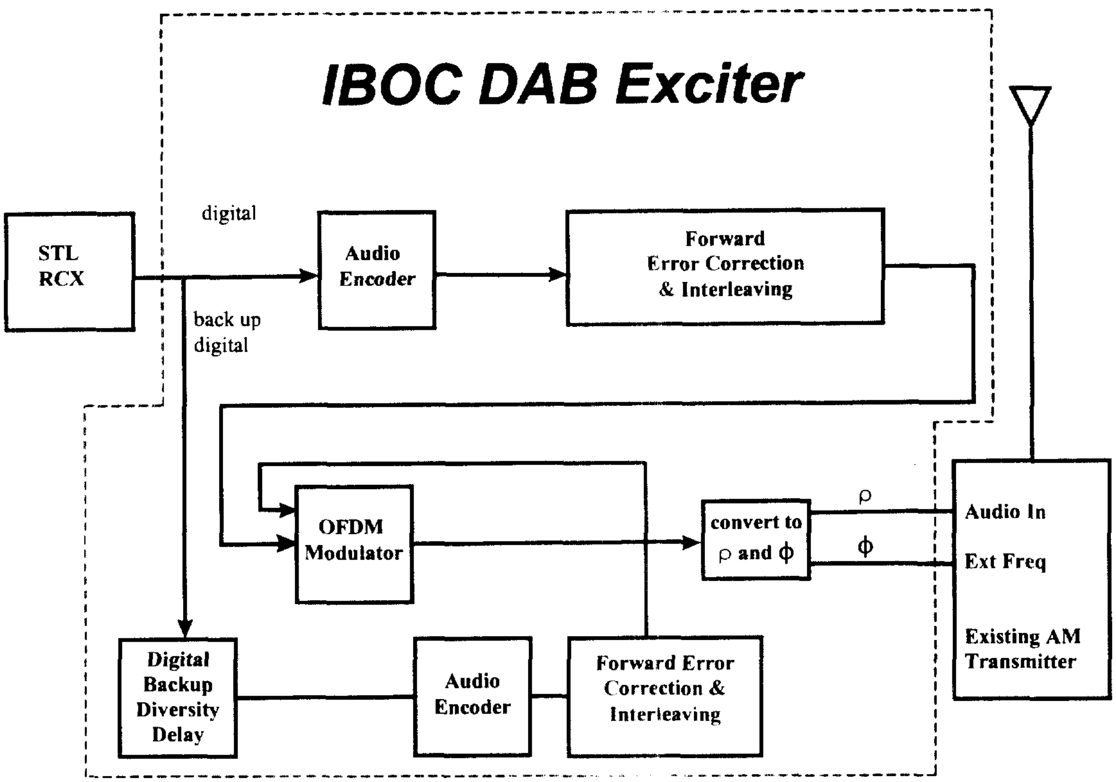

Figure 15 – All-Digital AM IBOC Transmitter block diagram

A functional block diagram of an AM IBOC receiver is presented in Figure 16. The signal is received by a conventional RF front end and converted to IF, in a manner similar to existing analog receivers. Unlike typical analog receivers, however, the signal is filtered, A/D converted at IF, and digitally downconverted to baseband in-phase and quadrature signal components. The hybrid signal is then split into analog and digital components. The analog component is then digitally demodulated to produce a digitally sampled audio signal. The digital signal is synchronized and demodulated into symbols. These symbols are deframed for subsequent deinterleaving and FEC decoding. The resulting bit stream is processed by the audio decoder to produce the digital stereo DAB output. This DAB audio signal is delayed the same amount of time as the analog signal was delayed at the transmitter. The audio blend function blends to the analog signal during station acquisition and if the digital signal is corrupted.

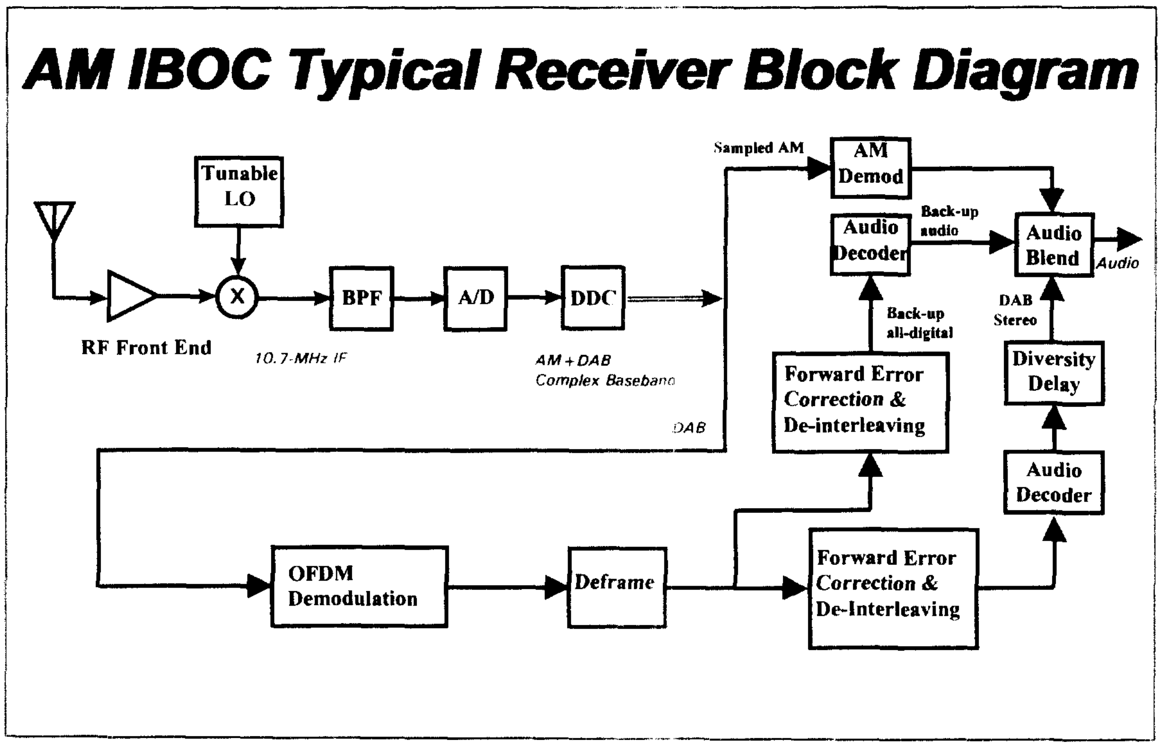

Figure 16. AM IBOC Receiver Block Diagram

For all-digital signals, low rate digital back-up channel path is shown with its own FEC. After deframing, the signal passes through a shorter interleaver with error correction. It is then applied to its audio decodec for use in the blend circuit

B. AM IBOC DAB System Performance and Compatibility[78]

1. Introduction

To verify that the USADR AM system design is capable of harmonious co-existence in both current and future environments, the system was modeled and simulated.[79] The computer simulations focused on two areas of compatibility: effects of IBOC signals on existing analog broadcasts, and performance of the IBOC digital signal in an environment comprised of both analog and IBOC signals.

The first group of simulations measured the degradation introduced by adding DAB to an analog AM signal and the effects of co-channel and adjacent-channel interference on an analog signal from an IBOC DAB signal. These investigations revealed that the addition of IBOC DAB carriers to an analog AM signal should not significantly affect audio quality. Since the power spectral density of the existing AM analog signal, the hybrid IBOC signal, and the all-digital IBOC signal are very similar, the interference from the co-channel and adjacent channel IBOC signals to the analog is no worse than what presently exists. Thus, the analyses indicate that existing analog service should not be significantly affected by introducing IBOC DAB signals to the environment.

The second group of simulations investigated performance of hybrid and all-digital IBOC signals in the presence of various combinations of co- and adjacent-channel analog, hybrid

[78] Appendix H contains a detailed discussion of the results presented below as well as USADR's methodology and analysis.

[79] The methodology, simulation and results of USADR were independently verified by recognized communication experts. A report by Dr. D.L. Pickholtz and Dr. B.R. Vojcic is presented in Appendix I.

IBOC, and all-digital IBOC signals. The simulations indicate the relative levels of co-channel or adjacent channel interference that can be tolerated by the digital portion of the hybrid signal. For the AM hybrid IBOC signal in a benign channel, the levels of co-channel and adjacent channel interference that can be tolerated (19.5 dB to 28 dB for single or dual interferers) is similar to the protected SNR level resulting from a co-channel interferer (i.e. 26 dB). The degree of coverage depends on the number, type, and level of the interfering signals.

2. <u>Analog AM performance in the presence of IBOC signals</u>

Impact of digital signal on analog host AM performance

The AM hybrid system employs several techniques to minimize the interference from the digital carriers to the analog AM host signal. These techniques include:

- Placement of the digital carriers that are in the analog bandwidth (±5 kHz) in quadrature to the analog signal.
- Appropriate setting of the power levels of the digital carriers that are placed within the analog bandwidth (±5 kHz).
- Spectral sidelobe reduction to minimize leakage from digital carriers that lie on either side of the analog signal.
- Dynamic predistortion technique to "precancel" the interference that the digital signal places in the analog AM envelope detector of the receiver.

The first three techniques alone can theoretically limit the interference from the digital signal to its analog host to yield about 56 dB SNR (ref. 100% modulation), as described in Appendix H. Dynamic predistortion can reduce this interference even further. Although this interference in new receivers can be made arbitrarily small, the interference in existing receivers is limited by the non-ideal IF filter asymmetry.

Preliminary experiments with automobile receivers using a previous 30 kHz AM DAB signal, without the benefit of dynamic predistortion, indicate that good SNRs can be obtained with most receivers. However, there are some receivers with significant IF filter asymmetry that are more sensitive to this problem. The present 20 kHz AM DAB signal is designed to reduce this interference even further.

Analog performance with co-and adjacent channel IBOC DAB signals

Hybrid and all-digital IBOC signals will be transmitted with power spectral densities comparable to existing AM analog signals. The interference from co-channel or adjacent-channel IBOC interferers will be comparable to the interference from present AM analog signals. Consequently, the IBOC DAB signal is compatible with the existing analog environment, and the constant white noise interference of DAB is likely to be less annoying than the present analog co- and adjacent channel interference at comparable D/U ratios.

3. <u>Hybrid digital system performance</u>

Performance in presence of Gaussian noise

Simulations were initially performed in Gaussian noise only, in the absence of other channel impairments and interference. The Gaussian noise tests were performed to ensure that the signal and noise levels were calibrated, and that the detection of individual digital carriers achieved near expected theoretical performance.

Tests determined the relative signal and noise levels required to achieve a 1% Block error rate, which is the rate at which the audio impairment is just barely audible. It is called the Threshold of Audibility ("TOA"). USADR defines the Carrier-to-Noise ratio ("CNR") as the ratio of the power in the AM main carrier to the power in a single digital carrier. This ratio is defined for calibration convenience, and is not the same as the SNR in a single digital carrier.[80]

At the TOA, the CNR=58 dB for the 48 kbps audio codec, 56 dB for the 32 kbps audio codec, and 54 dB for the 16 kbps audio codec. These results confirm the expected performance so that there is confidence that the system is correctly simulated.

Performance with co-channel and adjacent channel hybrid interferers

Tests were performed to determine the TOA in the presence of co-channel and adjacent channel interferers. The levels of the three interferers (lower and upper first-adjacents, and co-channel) were adjusted relative to the desired signal resulting in a D/U for each. The minimum level of any of the three interferers was limited to 50 dB D/U in lieu of any other noise or channel impairments for these tests.

Results of the tests with a single significant interferer revealed that the TOA is reached with a single co-channel D/U of 19.5 dB for the 32 kbps codec, and 29 dB for the 48 kbps codec. Similar results for a single first-adjacent interferer indicated that the TOA was reached with a D/U of 20.5 dB for the 32 kbps codec and 25.5 dB for the 48 kbps codec.

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80 For example, the signal power in a single digital carrier can be -44 dB relative to the main carrier, resulting in a 12 dB SNR when the CNR defined here is 56 dB.

Performance with a second adjacent interferer revealed that no impairment was measured when the second-adjacent was 30 dB larger than the desired signal (D/U=-30 dB). This high immunity from second adjacent interference is due to the spectral occupancies not overlapping. Therefore, no further testing with second adjacent interferers was performed.

Tests with pairs of significant interferers determined the TOA with various combinations of interference levels from co-channel and first adjacent interferers. For example, the TOA is reached when both first adjacents were set at a D/U of 25 dB for the 32 kbps codec, and 28dB for the 48 kbps codec. The TOA is reached when both the co-channel and a first adjacent were set at a D/U of 26 dB for the 32 kbps codec, and 31 dB for the 48 kbps codec.

Interference summary

It can be seen that the D/U ranges for determining the TOA above are roughly comparable to the D/U level of 26 dB presently used as the protection ratio for a co-channel interferer for AM analog reception. Therefore, simulation and analyses indicate that the IBOC DAB signal will be compatible with both existing and future radio frequency environments. Existing analog stations should not be adversely affected by the introduction of co-channel or adjacent channel interference. In addition, IBOC DAB signals should provide high quality DAB coverage over areas where the existing analog AM signal has an D/U of roughly 26 dB, or greater. Since the IBOC signal from the all-digital mode has higher power digital carriers in the center 10 kHz of the channel it will provide a substantially greater digital coverage than its hybrid counterpart.

VIII. IBOC DAB EQUIPMENT

A. Receivers

It is anticipated that receivers will be sold to the public through the existing manufacturers and distribution channels. In appearance, the digital capable radios are similar to the analog receivers of today, except that several internal digital processing components are included.

Advances in digital processing and semiconductor technology make digital radio receivers affordable. As described earlier, the design and manufacture of digital receivers is relatively straight-forward. Many components found in today's analog receivers will be used in its digital counterpart. For example, a typical car receiver, not including speakers, consists of approximately eight major component categories: RF front end, IF circuit, demodulator, audio processor, audio amplifier, controller, power supply/DC conditioner, chasis/front panel and, in some units, a cassette or CD transport. Some modifications to the controller software, the RF front end, IF circuit, and demodulator are needed, but, overall, radio will enjoy a relatively cost effective upgrade (especially when compared to the new DTV receiver) . Many of these cost component categories are not changed when implementing digital. Some modifications to the controller software, the RF front end, IF circuit, and demodulator are needed, but overall, radio will enjoy a relatively cost effective upgrade (especially when compared to the new DTV receiver).

Although digital radio receivers require more complex digital processing, a number of components from analog radios can be re-used. Thus, a consumer price for digital will be only marginally more expensive than for analog receivers. In digital receivers, the primary increase in cost comes from the digital processing circuitry used to decode the digital and analog audio signals. This circuitry replaces the existing analog IF and demodulation. There will be an additional small increase in the cost of the RF front end. By comparison, in today's analog receivers, the RF front end, IF circuit and demodulator represent approximately 10% to 15% of typical manufacturing cost. On-going improvements in digital processing capabilities and volume cost reductions in semiconductor manufacturing indicate that the additional digital processing components will still represent a fraction of the total cost of the receiver. Therefore, the increase in cost during the initial years of product introduction will be only marginal.

B. Transmitters/Exciters

It is expected that the manufacturers of analog transmitters will also produce digital transmitters and make them available to radio stations through the normal distribution channels. A radio station will need an IBOC compatible transmitter and a digital exciter to transmit the digital signal.

In order to transmit a digital AM signal, AM transmitters must be designed to meet low distortion and noise specifications. Some current models of analog transmitters are compatible with IBOC broadcasting. In order to transmit IBOC, the station also needs to add an AM IBOC exciter to an IBOC compatible transmitter.

In order to transmit a digital FM signal, FM transmitters must be designed to pass the IBOC signal. Currently, there are no broadcast transmitters which are IBOC compatible.

Manufacturers must design the transmitters to pass the digital waveform. In addition, an exciter must be incorporated into the transmitter, or added externally, to generate the digital signal.

The inclusion of digital processing technology in transmitters and the need to acquire a digital exciter to generate digital waveforms will initially result in somewhat higher costs. However, the cost of this equipment should not be excessive compared to the normal capital cost improvements faced by the industry in general.

IX. REGULATORY ISSUES

USADR has compiled in Appendix A hereto several proposed changes to the existing Part 73 rules to authorize IBOC DAB in the United States. USADR encourages the Commission to expeditiously implement the necessary rule changes to bring the benefits of IBOC DAB to the public as quickly as possible. The Commission has long-standing policies supporting the efficient use of the electromagnetic spectrum through careful spectrum management, the promotion of spectrum sharing where technically feasible, and the use of frequency-efficient technology.[81] At the same time, the Communications Act and the Commission's most basic policies encourage the prompt authorization of technology that can offer tangible benefits and

[81] *See Third Report and Order and Memorandum Opinion and Order* in ET Docket No. 92-9, 8 FCC Rcd 6589, 6612 (1993) (emphasizing the Commission's commitment "to providing spectrum for the development and growth of new services to the American public"); *Fourth Further Notice of Proposed Rulemaking and Third Notice of Inquiry* in MM Docket No. 87-268, 10 FCC Rcd 10,540, 10,541 (1995) (goals of DTV proceeding included promoting spectrum efficiency to allow public full benefit of spectrum and ensuring spectrum used in manner that best serves public interest).

enhanced service to the public consistent with the requirements of the Communications Act.[82] Authorizing DAB and designating IBOC as the appropriate means to implement digital radio will serve the public interest.

USADR therefore urges the Commission to initiate immediately a rulemaking proceeding to develop rules for DAB. This rulemaking should culminate with the adoption of rules that allow the introduction of IBOC DAB in the United States, including the establishment of a DAB transmission standard. More specifically, USADR requests that the Commission take the following regulatory steps to implement IBOC DAB in the United States.

- Find that IBOC is the most appropriate means to implement DAB in the United States.
- Establish interference protection criteria to ensure the compatibility of all radio stations, both analog and digital, during and after the transition period.
- Establish *ab initio* a transition plan that provides appropriate protection for analog radio for an interim period but also fosters the transition to an all-digital environment.[83]

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82 *See* Communications Act of 1934, as amended, 47 U.S.C. § 157 (stating it is "the policy of the United States to encourage the provision of new technologies and services to the public"); Telecommunications Act of 1996, § 706(a), Pub. L. No. 104-104, 110 Stat. 56 (directing the Commission to "encourage the deployment on a reasonable and timely basis of advanced telecommunications capability to all Americans").

83 Adopting the proposed rules in Appendix A would accomplish these tasks.

- Adopt a DAB transmission standard that will ensure that all DAB radios are compatible with all DAB transmitters. and will enable the continuation of a ubiquitous and free radio service in the United States.
- Establish criteria for evaluating alternative IBOC systems and a timetable for the submission of IBOC system information to the Commission for evaluation.
- Select a single IBOC system to be implemented in the United States and adopt a transmission standard that allows implementation of the selected system.

A. The Commission Should Designate IBOC DAB as the Appropriate Means to Implement Digital Radio.

USADR has demonstrated herein the benefits to the public that will flow from the enhanced audio quality, increased signal robustness and availability of auxiliary services to be offered by DAB. USADR has also shown the viability and advantages of the IBOC DAB approach. IBOC DAB provides a rational transition from analog to digital and offers immediately enhanced service without disruptions to the existing analog radio service or the need for adjustments in consumer patterns of use. IBOC DAB allows this to be achieved without the need for new frequency allocations, the issuance of new licenses or the creation of a new regulatory structure. Finally. USADR has demonstrated the technical viability of its IBOC DAB technology. Based on this record, USADR believes that the Commission should immediately make a finding that IBOC will be the method of DAB transmission in the United States.

B. The Commission Should Develop Interference Protection Criteria

The introduction of IBOC DAB will further complicate the very complex interference environment which exists today in the AM and FM bands. In order to insure the continued viability of existing analog radio during the transition period and simultaneously provide an environment for DAB to prosper, the Commission should develop interference criteria for both the interim hybrid period and the all-digital period. Broadcasters will have little incentive to implement DAB if it entails putting their access to the listening public at risk. When broadcasters first upgrade to the hybrid mode, there will be few DAB receivers in use. Broadcasters (both those upgrading immediately to digital and those remaining in analog mode for a period of time) will need some assurance that listeners will be able to use their analog receivers during the transition period. Without interference rules, no such assurances can be given to broadcasters or listeners.

Currently, the FCC uses emissions masks to ensure that an individual analog station's transmission does not interfere with adjacent analog stations. An emissions mask limits the power and bandwidth of the energy transmitted by an individual radio station. Emissions masks should also be the regulatory foundation to ensure compatibility between adjacent radio stations once IBOC DAB is introduced. In order to ensure compatibility in an IBOC DAB world, several emission masks will be necessary. First, the current analog emissions mask as defined in Sections 73.317 and 73.44 of the Commission's rules for FM and AM, respectively, would continue to apply to all stations as long as they transmit in an analog-only mode. Second, any FM station that simultaneously transmits analog and digital signals in the hybrid mode will be required to meet a new FM hybrid mask for the combined analog and digital transmissions. Likewise, any AM station that seeks to transmit in the hybrid mode will have to comply with a new AM hybrid emissions mask for the combined analog and digital transmissions. Third, in the all-digital period, a new FM DAB emissions mask will become effective that will allow the broadcaster to increase the power and bandwidth of the digital signal. The new all-digital FM mask will improve the coverage and robustness of the FM DAB signal and increase FM broadcasters' auxiliary service offerings.[84] It is unnecessary to adopt a new AM emissions mask at the end of the interim hybrid period because when the AM analog signal is turned off, the power of the digital signal can be increased, consistent with the AM hybrid emissions mask. Thus, a new all-digital AM mask is not necessary.

The establishment of "rules of the road" through adoption of interference protection criteria is a fundamental responsibility of the Commission. Here, the requirement to establish such criteria to facilitate the introduction of IBOC DAB is self-evident. Thus, USADR urges the Commission to adopt emissions masks that will facilitate the prompt introduction of DAB radio in the United States.[85]

C. <u>The Commission Should Establish Rules that Facilitate the Efficient Transition to All-Digital Environment</u>

In order to give consumers, broadcasters, and equipment manufacturers confidence in the development of IBOC DAB, it is important that the Commission establish from the outset a plan

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[84] It will result, however, in a possible reduction of coverage for adjacent analog FM stations.

[85] Appendix A to this Petition contains proposed emissions masks for the USADR IBOC DAB system.

for the transition from an analog to an all-digital environment. A transition plan must ensure that the public is not harmed during the transition from analog to the interim hybrid period, or to the all-digital period. At the same time, it must provide incentives for consumers to purchase digital receivers, broadcasters to upgrade to digital, and transmitter manufacturers to produce new transmitters.[86]

USADR has demonstrated herein that its IBOC DAB technology inherently provides the flexibility needed to satisfy these goals. For the listener, the flexibility inherent in the USADR IBOC DAB system design will allow a seamless transition to digital. Listeners can make the choice to purchase digital receivers based on the enhancements and features associated with the product. Since IBOC DAB receivers will be only marginally more expensive than analog receivers and IBOC DAB will not require adjustments in consumer behavior, there should be strong market penetration of DAB.

Likewise, broadcasters will have significant flexibility in determining when to upgrade to digital. IBOC will allow broadcasters to immediately introduce DAB without impairing existing analog transmissions and without interrupting service to the public. Factors that may be relevant to a broadcaster's decision to upgrade to digital might include listeners' requirements, DAB receiver penetration, a station's programming format, the topographic conditions in the area in which it operates, the actions of competing stations which offer digital broadcasts, and the demand for auxiliary services. Some stations might employ digital radio transmissions early in

[86] An economic analysis of standard-setting and transition issues prepared by Stanley M. Besen and John M. Gale of Charles River Associates appears in Appendix B (hereinafter the "CRA Report").

the transition period from an analog to an all-digital environment, whereas others might do so much later. It is possible that some stations, particularly financially constrained ones, will upgrade to DAB only when there is an independent need to replace the transmitter. Thus, the pace at which an individual broadcaster upgrades to digital may be influenced by the age and condition of existing analog transmitters.

USADR anticipates that the unique features of IBOC DAB will facilitate implementation of a transition plan that avoids much of the complexity and controversy the Commission faced in upgrades of other analog services. Specifically, there is no need for the Commission to establish an end of service date for analog radio. An analog "sunset" is unnecessary because the IBOC DAB signal will occupy the existing analog radio frequency, thereby eliminating the need to reclaim unused analog spectrum. This facilitates a seamless transition from analog to digital.

Notwithstanding the benefits of the flexibility of the USADR IBOC DAB system, the Commission will need to establish a minimum number of guidelines to ensure that listeners can obtain the maximum benefits of DAB and that the transition is effective. Specifically, an excessively long or indeterminate transition period could retard the introduction of DAB technology. This is because listeners or broadcasters might adopt a "wait and see" attitude, moving to purchase DAB radios only after a substantial number of others have done so. In anticipation of this problem and to provide a smooth transition, USADR proposes the following rules:[87]

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[87] The text of these proposed rules is set out in Appendix A.